PLASMA PHYSICS ABSTRACTS

1 JANUARY 1968 through 31 DECEMBER 1968

by

David C. Montgomery
Donald A. Gurnett

Department of Physics and Astronomy
THE UNIVERSITY OF IOWA
Iowa City, Iowa

PLASMA PHYSICS ABSTRACTS

1 JANUARY 1968 through 31 DECEMBER 1968

by

David C. Montgomery
Donald A. Gurnett

This collection of abstracts represents those plasma physics publications from the University of Iowa during the above period which are considered relevant to NASA Grant NGR-16-001-043.

A similar collection of abstracts was issued on December 31, 1967. The numbering scheme continues consecutively with that which was used in this earlier report.

A. THEORETICAL

18. Response of a One-Dimensional Vlasov Plasma to External Electric Fields
R. C. Harding
Physics of Fluids, 11, 2233 (1968)

The nonlinear response of a Vlasov plasma has been calculated numerically for several externally applied electric field configurations. In the presence of a standing wave of frequency $\omega_0 \gtrsim \omega_{pe}$, the energy of the particle distribution and the envelope of the particle electric field were found to oscillate slowly with approximately the period of the trapped particles. Analogous spatial oscillations have been reported by Malmberg and Wharton. Bernstein, Greene, and Kruskal equilibria were calculated for a constant, sinusoidal inhomogeneity in the background ion charge density and found to be numerically stable against small perturbations. Landau-damping rates for the perturbations are compared with the calculations of Jackson and Raether. In the presence of a slowly varying ($\omega_0 << \omega_{pe}$) inhomogeneous background (simulating an ion acoustic wave) the electrons were found to obey a locally isothermal equation of state to within a few percent for the times that could be calculated. The response of an initially uniform plasma to a suddenly applied external field was also calculated.

19. Scattering of Charged Particles in a Weakly Turbulent Plasma
Celso Roqué
Physics of Fluids, 11, 2471 (1968)

The mean-square deflection of suprathermal test particles from a weakly unstable electron plasma is calculated. The instability is assumed to have been driven by a tenuous beam of energetic electrons. The random phase approximation expression for the spectral density is used and the electric field energy density of the turbulent spectrum is estimated by the quasilinear theory. It is shown that the mean-square scattering angle can be increased by more than an order of magnitude by a suitable beam

density or drift velocity. This enhances the potential usefulness of charged-particle scattering as a diagnostic tool for turbulent laboratory plasmas.

20. Numerical Studies of Turbulent Heating
S. Peter Gary and David Montgomery
[accepted for publication by Physics of Fluids; to appear in December 1968 issue]

We have numerically integrated the equations of motion of electrons subject to different combinations of electrostatic waves. We ignore magnetic fields throughout. We calculate, for particular choices of wave amplitude, wave number, frequency, and phase, and for given initial velocities, the mean square velocity spreading of a collection of particles subject to three different kinds of wave spectra: (a) a single monochromatic wave; (b) several (up to ten) monochromatic waves with differing phase velocities; and (c) a single wave with a random phase change at regular intervals. Heating occurs due to two basic effects: the "trapping" of particles, operative in all three spectra, and the spreading of the spectral density due to the random phase interruptions in (c). For the parameters chosen, numerical results are that the most efficient heating occurs in case (c).

21. Shock-like Solutions of the Electrostatic Vlasov Equation
David Montgomery
[accepted for publication by Journal of Plasma Physics]

It is shown how to construct shock-like time independent solutions of the electrostatic Vlasov and Poisson Equations in one dimension. The positive ions are assumed to be at zero temperature. The electrostatic potential is assumed to increase monotonically through the shock from zero to a constant value. The most important feature of the solution is a population of trapped electrons in the shocked plasma. In contrast to time-independent solutions based upon fluid equations, there is no upper limit on the amplitude of the shock.

22. Nonlinear Vlasov Plasmas: Initial Value Problem and Response to an External Field
David Montgomery
[to be published in Proceedings of Summer School on "Statistical Physics of Charged Particle Systems," Kyoto, Japan, Sept. 2-6, 1968; by Benjamin (U. S.) and Syokabo (Japan)]

Numerical solutions of collisionless plasma problems due to Armstrong and Harding are reviewed. Phenomena considered are: (1) nonlinear Landau damping; (2) development of the two-stream instability; (3) response of a Vlasov plasma to a rapidly varying electric field; (4) response of a Vlasov plasma to a low-frequency electric field; (5) damping of perturbations on non-uniform equilibria; and (6) formation of a shielding cloud around test charges. In most cases it is concluded that physical interpretations by means of elementary arguments involving particle "trapping" are adequate (more precisely, involving the interaction of particles with field components which appear to them to be nearly time independent). Several additional problems which should be susceptible to the same techniques are suggested.

23. Numerical Studies of Nonlinear Ion Acoustic Waves
T. P. Armstrong (University of Kansas) and D. Montgomery
[Published by U. S. A. E. C. in: Proceedings of A. P. S. Topical Conference on Numerical Simulation of Plasma, Los Alamos, New Mexico, Sept. 18-20 (1968), Report LA-3990.]

The nonlinear Vlasov equation for ions coupled with a fluid model for the neutralizing electrons has been integrated numerically. Collisionless damping of ion acoustic waves has been observed in the model. The characteristics of the damping of large amplitude waves are qualitatively similar to experimental observations as well as to prior numerical calculations on the damping of electron plasma oscillations. Namely, the initial damping is more severe than that expected from linearized theory and the long time regime has smaller than the linear damping rate.

24. Numerical Study of Charged Particle Heating by Plasma Turbulence
S. Peter Gary and David Montgomery
[Published by U. S. A. E. C. in: Proceedings of A. P. S. Topical Conference on Numerical Simulation of Plasma, Los Alamos, New Mexico, Sept. 18-20 (1968), Report LA-3990.]

We report numerical calculations of the heating of charged particles by turbulent electric fields. The fields are given, and are not required to be self-consistently supported by the particles. Three types of wave spectra are treated, each of which is analytically unmanageable: (1) many waves, constant phases and velocities; (2) one wave, randomly interrupted phase; (3) one wave, slowly varying wave number at constant frequency. Large particle energization is found in the last two cases. In all three cases, the results can be qualitatively understood by elementary arguments related to particle "trapping."

25. Particle Acceleration by Electrostatic Waves with Spatially Varying Phase Velocities
S. P. Gary, David Montgomery, and Daniel W. Swift (University of Alaska)
Journal of Geophysical Research 73, 7524 (1968).

[No Abstract.]

26. Oscillations Present in Plasma-Electron Heating by an Electron Beam
I. Alexeff, G. E. Guest, D. Montgomery, R. V. Neidigh, and D. J. Rose (other authors from Oak Ridge National Laboratory)
Physical Review Letters 21, 344 (1968)

Oscillations of electrostatic fields present when electrons are strongly heated by electron-beam plasma interaction reveal large-amplitude oscillations with $\omega/k||\lesssim v_b$, the electron-beam speed; $\omega\approx\omega_{ce}/10$, where ω_{ce} is the electron gyrofrequency; coherence lengths of roughly a few wavelengths (<< plasma length); and maximum electrostatic potential in the wave approaching the applied beam voltage. A gross compatibility is found between the observed frequencies and wavelengths and the predictions of a linear theory.

27. Experimental Strong Turbulent Heating
R. V. Neidigh, I. Alexeff, G. E. Guest, W. D. Jones, D. C. Montgomery, D. J. Rose, W. L. Stirling (other authors from Oak Ridge National Laboratory)
Paper CN-24/L-2 at International Atomic Energy Agency Conference on Controlled Fusion, Novosibirsk, U. S. S. R. (August 1968)
[to be published in Proceedings.]

Experiments at ORNL are exploring the strong turbulent interaction between a steady-state, magnetically collimated electron beam and its self-generated plasma.

The technology to maximize ion heating is being developed in Burnout V, a simple mirror device with magnetic fields of 50-25-50 kG, and with an axial electron beam (6 A at 10 kV) which gives a beam power density in the plasma exceeding one kW cm^{-3}. Necessary, but not sufficient, evidence for a true thermonuclear temperature is the observed 10^3 sec^{-1} cm^{-3} plasma source of 3-MeV protons identifying D-D reactions. Spectral measurements of recombination radiation reveal a line width corresponding to an ion energy of 0.5 keV. Analysis of charge-exchanged neutral atoms reveals the energy spectrum in more detail with a maximum between 100-500 eV and as much as 10 percent near one keV. A flux of 3×10^{14} cm^{-2} sec^{-1} of 100 keV deuterons escapes the midplane perimeter. Calorimetric probes measure a plasma heating effect equivalent to 0.5 keV ion bombardment at 2.5×10^{12} cm^{-3}. The rate of decrease of spectral radiation toward the plasma center establishes an electron density of at least 2.5×10^{12} cm^{-3}. The confinement time, 2×10^{-4} sec estimated from density and energy balance, agrees well with the measured spectral-light decay time and is equivalent to hundreds of ion transits through the plasma. Ion heating has been observed to increase strongly with increasing magnetic field strength, suggesting a direction for future development.

28. Fluctuations in Monatomic Gases
David Montgomery
[submitted to Physics of Fluids]

We treat the problem of calculating distribution-function auto-correlations of the form $\langle f(\vec{x}_1,\vec{v}_1,\vec{t}_1) f(\vec{x}_2,\vec{v}_2,\vec{t}_2) \rangle$

for a dilute monatomic gas. Two-time probability distributions of the type introduced by Rostoker for the plasma case are used. A perturbation expansion in the density is performed on the generalized BBGKY hierarchy which results. It is shown that the problem of determining the fluctuation spectra can be reduced to solving for a function which obeys the linearized kinetic equation for a dilute neutral gas with a particular choice of initial conditions, a result previously obtained by van Leeuwen and Yip, using diagrammatic perturbation theory. In the limit of infinite wavelengths and hard-sphere interactions, this equation reduces to the linearized Boltzmann equation.

29. A Simple Gigacycle Correlator
I. Alexeff, R. V. Neidigh, and W. R. Wing (University of Iowa)
[transmitted to International Journal of Engineering Science]

A gigacycle (beyond 2000 Mc) correlator has been developed with commercially available components. The basic components comprise two sampling oscilloscopes, a pulse generator, an analogue multiplier, a waveform averager, and a display oscilloscope. The oscilloscope output permits "real time" display of the correlation functions as they are computed over 100 sampling points. The device can correlate over a time interval that is adjustable from 2 nsec to 100 μsec. The instrument offers an improvement in frequency response of three orders of magnitude over any of the automatic correlators presently in the literature. Its maximum sensitivity without preamplification is about 2 mV. Its particular advantage is that it needs no alterations of its commercially available components, leaving them free for individual conventional use. Use of a single sampling oscilloscope for correlation studies is also discussed.

30. Propagation of Ion Acoustic Waves in a Magnetic Field
Glenn Joyce (University of Iowa) and R. A. Dory (Oak Ridge National Laboratory)
[submitted to Physics of Fluids]

The properties of low frequency electrostatic waves propagating at various angles to a magnetic field in a plasma are studied. Numerical calculations are used to determine the phase velocities, group velocities, damping decrements and propagation directions for frequencies between zero and twice the ion cyclotron frequency. A model is presented which simulates experimental time-of-flight studies of finite wave packets generated by sine wave bursts.

B. IONOSPHERIC

8. Satellite Observations of VLF Emissions and Their Association with Energetic Charged Particles
Donald A. Gurnett
Paper presented at the NATO Advanced Study Institute July 31 - August 11, 1967, Earth's Particles and Fields (1968)

A summary of recent satellite observations of VLF emissions and their association with energetic charged particles is presented. Using data from the Injun 3 satellite maps of the broadband intensity of magnetospheric VLF emissions are shown as a function of invariant latitude and magnetic local time. Examples of the simultaneous occurrence of VLF emissions and energetic charged particle precipitation are discussed.

9. Microburst Phenomena, 3. An Association between Microbursts and VLF Chorus
M. N. Oliven and D. A. Gurnett
Journal of Geophysical Research, 73, 2355 (1968)

Observations made with the Injun 3 satellite of bursts of precipitating $E_e \geq 40$-kev electrons and of VLF chorus emission have revealed their simultaneous occurrence. Observed microbursts are always accompanied by a group of VLF chorus emissions; chorus is not necessarily accompanied by microbursts. The maximum region of microbursts occurrence from $0400 \leq$ magnetic local time ≤ 1300 and $65° \leq$ invariant latitude $\leq 70°$ lies well within the maximum region of chorus emissions from $0300 \leq$ magnetic local time ≤ 1500 and $55° \leq$ invariant latitude $\leq 75°$. It is not generally possible to find a one-to-one (burst to burst) correspondence between individual microbursts and VLF chorus bursts.

10. Observations of VLF Hiss at Very Low L Values
Donald A. Gurnett
Journal of Geophysical Research 73, 1096 (1968)

[No Abstract]

11. Morphology of VLF Emissions Observed with the Injun 3 Satellite
William W. L. Taylor and Donald A. Gurnett
Journal of Geophysical Research 73, 5615 (1968)

Results of a study of very low frequency (VLF) emissions observed with the Injun 3 satellite are presented. Approximately 1200 hours of VLF magnetic field strength data and approximately 6000 frequency spectra samples are investigated in this study. These data cover invariant latitudes up to 82°, all local times, and altitudes from 237 to 2785 km. Contour plots as a function of invariant latitude and magnetic local time giving the frequency of occurrence of VLF emissions above a given intensity are presented. The most intense VLF emissions observed by Injun 3 are found to occur between about 55 and 75° invariant latitude and during the local day, with the maximum intensity occurring at about 65° invariant latitude and about 8 to 10 hours magnetic local time. The region of most intense VLF emissions was found to move to lower latitudes during geomagnetically active periods. The principal types of VLF emissions occurring in this region are ELF hiss and chorus, with the ELF hiss usually being the most intense.

12. VLF Electric and Magnetic Fields Observed with the Javelin 8:45 Sounding Rocket
S. D. Shawhan and D. A. Gurnett
Journal of Geophysical Research 73, 5649 (1968)

A rocket VLF experiment flown from Wallops Island to an altitude of 763 km is described, and the experiment results are discussed. A noise band between about 7.5 and 30 kHz was observed with both the electric and magnetic receivers. The field geometry of this noise suggests that the noise is propagating perpendicular to the geomagnetic field and that the lower cutoff frequency may be the lower hybrid resonance frequency. Intense noise bursts below 1 kHz were observed on the electric antennas below 500-km altitude during both the upgoing and downgoing portions of the flight, but not on the loop antennas. The precession and spin modulation of this noise is not consistent with an interpretation of these noise bursts as being due to long wavelength electrostatic waves in the surrounding

plasma. We suggest that this electric antenna noise may be generated by the motion of the payload. The magnitude of the electric antenna impedance varied from a minimum of about 150 kilohms at 350-km altitude to about 600 kilohms at apogee. A large phase perturbation, usually inductive, was observed at altitudes below about 500 km whenever the antenna was aligned nearly parallel to the geomagnetic field. The electric field signal from the nosecone transmitter was attenuated much more rapidly than the magnetic field.

13. The Low Frequency Cutoff of ELF Emissions
D. A. Gurnett and T. B. Burns
Journal of Geophysical Research 73, 7437, (1968)

ELF and VLF radio noises observed by satellites in the ionosphere often have a very sharp lower cutoff frequency near the proton gyrofrequency. This paper summarizes the experimentally observed characteristics of this low frequency cutoff and proposes an explanation for the cutoff based on the reflection of downward propagating, extraordinary mode, waves near the two-ion cutoff frequency between the proton and helium gyrofrequencies. This explanation, if correct, provides the first direct evidence that chorus and ELF hiss emissions are generated at high altitudes (above 3000 km) and not near the base of the ionosphere.

Ground-based observations of 700 Hz noise bands near the auroral zone, previously attributable to proton cyclotron radiation at low altitudes in the ionosphere, can now be explained by this reflection mechanism. Other possibly related effects (such as multiple ELF noise bands and the reflection of whistlers at the two-ion cutoff frequency) are discussed.

14. VLF Emissions During Magnetic Storms and their Association with 40 keV Electrons
David P. Cauffman and Donald A. Gurnett
[accepted for publication in Journal of Geophysical Research, 1969]

Spectrograms of very low frequency radio noise recorded by University of Iowa satellite Injun 3 at invariant latitudes greater than 50°N are used to determine the behavior of VLF emissions during magnetic storms. Variations in the wide-band intensity of VLF emissions from L = 3 to L = 8 are studied for the period from 28 April to 28 August 1963 by means of the automatic gain control levels of the satellite VLF receiver.

During a sudden-commencement magnetic storm the VLF emission called polar chorus characteristically appears at the onset of the storm, may increase in upper frequency extent to $\sim$ 5 kHz, may change from spike to burst structure (normal chorus), occurs over the greatest area on the fourth day of the storm, subsequently fades into low frequency, spike-structure polar chorus again and eventually disappears into the ELF hiss band generally present. Chorus occurrence shows symmetry about the 9:00 - 21:00 magnetic local time meridian with a large maximum in magnetic morning and a smaller maximum in magnetic eveing. Daily regions of occurrence are shown for the duration of a prototypical storm.

15. Observations of Electrostatic Proton Cyclotron Harmonic Noise in the Ionosphere
S. R. Mosier and D. A. Gurnett
[submitted to Nature, 1969]

[No Abstract]